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Procedia Environmental Sciences 12 (2012) 310 – 317

Procedia

Environmental Sciences

2011 International Conference on Environmental Science and Engineering
(ICESE 2011)

Effect of Distribution Patterns of *Artemisia sphaerocephala* on Soil Wind Erosion: a Field Evaluation of Wind Speed Profile and Roughness

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Abstract

The shrubs of *Artemisia sphaerocephala* show different patterns were investigated in the Mu Us Sandy Land of north central China. Supported by field observation and, based on the understanding of wind field distribution and wind energy change, the mechanism of planting disposition to prevent soil wind erosion was analyzed using aerodynamics principle. The result indicates that the wind speed profile of *Artemisia sphaerocephala* with banding collocate, uniformity, and stochastic model all follow one-variable linear regression. The rate of change of wind velocity in shrubs with “banding collocate model” is biggest, the one with “uniformity model” comes second, and the one with “stochastic model” is the smallest. Under the same condition of vegetation coverage, the variation tendency of the stability of surface roughness and the average windbreak effect for three distribution modes is the same as that of rate of change of wind velocity. The shrubs of *Artemisia sphaerocephala* with “banding collocate model” reduce the wind velocity at 20cm and are remarkably superior to that of the other two. At the height of 50cm, the effect of windbreak for the shrubs with “banding collocate model” are 22.9% higher than the one with stochastic model, but there is a significant between the shrubs with “banding collocate model” and “uniformity model”. From this we can find out the shrubs of *Artemisia sphaerocephala* with the banding collocate model is optimum for controlling wind erosion.

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Keywords: Component: Mu Us Sandland; Distribution pattern; Soil Wind Erosion; Wind Speed Profile; Roughness

1. Introduction

Factors such as shape, flexibility, distribution pattern, etc. are extremely important in preventing soil wind erosion. However, researches in the past used to focus on coverage only, without further consideration of comprehensive effects of the above factors. Research was done in wind tunnel to study how plants would influence soil wind erosion through disturbance on airflow surface. It showed that given the same coverage, uniformity distribution would have larger effect on weakening soil wind erosion. But it did no further study. The shrub of *Artemisia sphaerocephala* are widely distributed in many habitats like the semi-fixed sandy land, fixed sandy land, lowland with sand cover and ridge-land, which are perfect sand fixing afforestation plant. This paper studies different configurations of *Artemisia sphaerocephala*, which is the main constructive species in Mu Us Sandland, and can be used as basic-consideration in configuration selection when constructing shrubbery in arid and semi arid areas.

2. Sample Plot Situation

The selected sample plot, 38°57'~39°01' N. latitude and 109°02'~109°17'E. longitude, with altitude of 1300m~1600m, is located within Tuke County, Wushen Banner, Erdos City, Inner Mongolia, which is the hinterland of Mu Us Sandland. It lies in a temperate transition climatic zone between arid and semi-arid. Rainfall concentrates in July, August and September, annual precipitation is about 360mm, but annual evaporation is 2100mm~2600mm. Its dryness degree is 1.6~2.0. It has 2700h~3100h annual hours of sunshine, and its temperature $\geq 10^{\circ}\text{C}$ can accumulate $2500^{\circ}\text{C}\sim 3200^{\circ}\text{C}$. Its average annual temperature is $6^{\circ}\text{C}\sim 8^{\circ}\text{C}$, with the highest of $20^{\circ}\text{C}\sim 24^{\circ}\text{C}$ in July and the lowest of $-12^{\circ}\text{C}\sim -8^{\circ}\text{C}$ in January. Its duration of frost-free period is 130d~160d. Its annual average wind velocity is 3.3ms, mainly northwesterly gale between April and May, there will be 40d~50d of strong wind and flying sand.

3. Material and methods

3.1 Material

Three types of configuration of indigenous *Artemisia sphaerocephala* shrubbery whose coverage is 20%~25% are selected. *Artemisia sphaerocephala* is deep root, its taproots can reach as deep as 150cm and the lateral roots can stretch as wide as 130cm, and the longest root piece is 90cm. In this view, it is strong in drought combat and has become a key constructing bush species in Mu Us Sandland. The research is done in early April, in which time branches are not open up and leaves are not thick, then wind has the most serious influence on earth's surface. Therefore, it is of great significance to study the effects of its horizontal distribution pattern on soil wind erosion at this time.

3.2 Experimental methods

1) Uniformity model

The selected sample plot is to the northwest of China Desert Research Center, and has an area of more than 4hm². Main wind direction is northwestern. *Artemisia sphaerocephala* plants within are 0.6~0.8m high in average, with spacing of 2×3m and coverage of 23%~25%. Underlying *Artemisia sphaerocephala* plants are semi-fixed sands and a small amount of herbs (those within the plot are removed). Within the plot, 22 experimental points are set up, 21 of them are set in the shrubbery down the wind in 6 rows. Row-row space is 4m. Every odd row has 2 points with space of 3m, and every even row has 5 points with space

of 1m. The left 1 point is set beyond the shrubbery, ideally empty and high area without influence from plants. Considering that PC-2F can test no more than 10 points at one time, then the left one point is fixed, and another 8 points will be tested everytime, the test finishes after 3 times. At the same time, wind velocity tests are going on at two heights, 20cm and 50cm. Besides, wind profile is observed simultaneously at 8 heights, 20cm, 40cm, 60cm, 80cm, 100cm, 120cm, 180cm and 200cm, time interval is 1s, observation duration is 17 min.

2) Stochastic model

Selected sample plot locates the same with uniformity model, it is 35m×35m in shape. Main wind direction is northwestern. *Artemisia sphaerocephala* plants within are 0.6~0.8m high in average, with coverage <25%. Underlying *Artemisia sphaerocephala* plants are semi-fixed sands and a small amount of herbs(those within the plot are removed). Within the plot, 19 experimental points are set up down the wind, 18 of them are within the shrubbery, and 1 is in the upwind direction, ideally in empty and high area without influence from plants. Test methods are the same with uniformity model.

3) Banding collocate

Five bands of *Artemisia sphaerocephala* are selected, each band is 5m wide. Plants interval space is 1m, plants height is about 0.6m, and coverage is 20%. Totally 19 experimental points are set down the wind, of which 2 are before the bands, ideally in empty and high area without influence from plants. The other 17 ones are set afterwards with interval space of 1m. In view of PC-2F's test ability, the farthest one in empty area is fixed. Wind velocity tests are going on at the same time at heights of 20cm and 50cm, besides, wind profile is observed too.

3.3 Analyzing methods

4) Observation on wind speed profile

Optimal fitting formula to calculate aerodynamic roughness by measured wind velocity at different heights is:

$$u_z = A + B \ln z$$

Where u_z is wind velocity at height z ; A , B are regression modulus. If $u_z=0$, then $z_0 = \exp(\frac{-A}{B})$.

5) Roughness Calculation

Once wind velocity u_1 、 u_2 at two random heights Z_1 、 Z_2 are measured, roughness can be calculated by:

$$\log Z_0 = \frac{\log u_2 - A \log u_1}{1 - A}, \text{ where } A = u_2 / u_1$$

4. Results analysis

4.1 Wind profile analysis

Continuous observation, during which no sand flow occurs, produces 1000 groups of data. Firstly, do convert average wind velocity values at a same height into wind velocity at a same moment, then, conduct regression analysis, see results in Table 1, according to which Figure 1 of average wind velocity profile can be made.

It can be seen from Table 1 that, wind profile of above three models all follow one-variable linear regression, and velocity increases as getting higher. But banding collocate has the largest slope of 3.13,

that is to say, wind velocity changes the most. On the contrary, stochastic model has the smallest slope of 1.36, 43.2% of that of banding collocate. As wind velocity in banding collocate decreases the most and in stochastic model the least, with uniformity model between them, then, it can be concluded that banding collocate is most effective in preventing soil wind erosion.

Table 1 Average wind velocity at different heights

Height(cm)	20	40	60	80	100	120	180	200
Niformity	4.42	4.79	5.32	6.41	6.92	7.29	8.25	8.23
Banding	3.36	3.82	4.80	5.77	6.37	6.9	7.79	8.00
Stochastic	2.91	3.59	3.91	4.15	4.29	4.39	4.82	4.78

4.2 Roughness analysis

By measuring wind velocity at heights of 20cm and 200cm in forests of all three models, surface roughness is calculated as Table 2.

Table 2 Roughness analysis in *Artemisia sphaerocephala* shrubbery of three models

Velocity	Banding	Uniformity	Stochastic
4~5m/s	1.20	1.33	0.53
5~6m/s	1.16	1.11	0.32
6~7m/s	1.07	0.92	0.22
7~8 m/s	1.05	0.85	0.10

Table 2 shows that, surface roughness decreases as wind velocity increases. Given the same coverage, banding collocate has the most stable surface roughness, with variability of 1.19. While stochastic has a small roughness but changes a lot, whose variability is 5.49. As a result, in *Artemisia sphaerocephala* shrubbery of stochastic model, partial wind erosion occurs easily. Variability of uniformity model is between the other two, however, if comparison wind velocity <5m/s, its roughness is larger than that of banding collocate, on the contrary, if comparison wind velocity >5m/s, the result is contrary. Therefore, *Artemisia sphaerocephala* shrubbery of banding collocate is the most effective for preventing soil wind erosion.

4.3 Windbreak effect analysis

In the research, every experimental point in three models get 1000 groups of data each. Then, average wind velocity values $\overline{u_{20}}$ and $\overline{u_{50}}$ of every point can be calculated and standardized calculated compared with control points. Figure 3 to Figure 8 shows wind flows at 20cm and 50cm of all three models.

It is shown from the test results that, total average wind velocity at the mentioned two heights in banding collocate is 66.1% of that of control points, while in stochastic model it is 98.1% and in uniformity model it is 79.9%. In terms of average windbreak effects, given the same density, in stochastic model it is 32.0% weaker than that in banding collocate and 18.2% weaker than that in uniformity model. As to windbreak effects at different heights within the shrubbery, in banding collocate, wind velocity decreases the most at 20cm, 41.8% lower than the control point, its windbreak effect is 41.2% stronger than stochastic model and 14.1% stronger than uniformity model; also in banding collocate, wind velocity at 50cm is 26.1% lower than the control point, and windbreak effect is 22.9% stronger than stochastic model but has no difference with uniformity model.

If study further, it can be seen that, the higher wind velocity is, the stronger wind preventing effects are, no matter which model, but in banding collocate, it prevent the most. In addition, wind flow in banding

collocate is relatively stable, but changes complexly in stochastic model, with uniformity model between the first two.

5. Conclusion

Wind profile in *Artemisia sphaerocephala* shrubbery of the three models, banding collocate, uniformity model and stochastic model, all follow one-variable linear regression. The higher, the larger wind velocity is. Wind velocity decreases the most in banding collocate and the least in stochastic model, with uniformity between them.

Given the same coverage, surface roughness in banding collocate is the most stable, while in stochastic model it is small but changes a lot, its variability is 5.49, surface roughness of uniformity model comes between the other two. Given the same density, the average windbreak effect in stochastic model is 32.0% lower than that in banding collocate and 18.2% lower than that in uniformity model.

In terms of windbreak effects at different heights within the shrubbery, when it is at 20cm, it is the most effective in banding collocate, 41.2% stronger than in stochastic model and 14.1% stronger than in uniformity model; when it is at 50cm, windbreak effect in banding collocate is 22.9% stronger than that in stochastic model but has no difference with in uniformity model.

It can be concluded that *Artemisia sphaerocephala* shrubbery in banding collocate has the strongest effects in preventing soil wind erosion.

6. Acknowledgment

The authors wish to express their gratitude to Dr. Wang Jiping, who helped to improve the paper through a thorough review. The author would like to thank the reviewers for their valuable comments.

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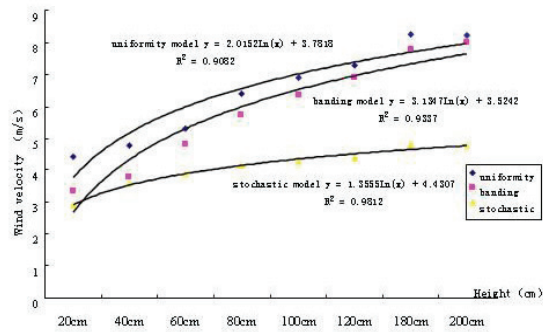


Figure1 Wind profile at different heights in three models

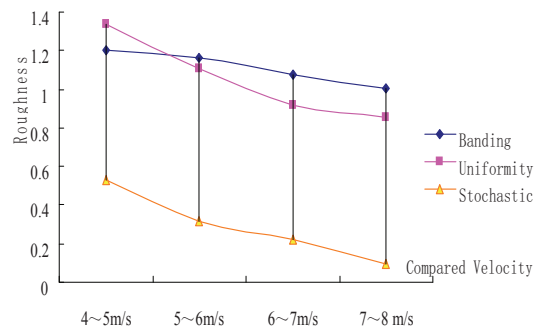


Figure 2 Roughness comparisons among three models

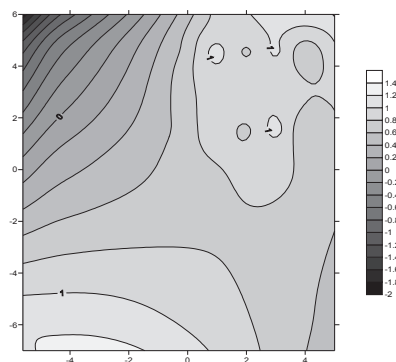


Figure 3 Wind velocity at 20cm in uniformity model

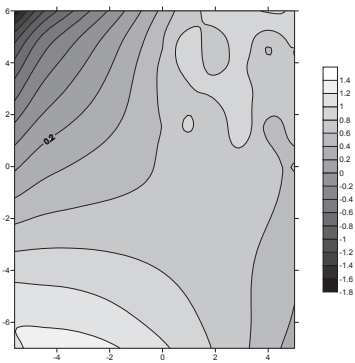


Figure 4 Wind velocity at 50cm in uniformity model

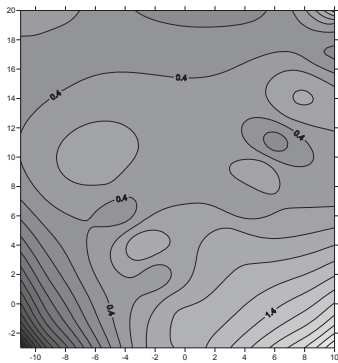


Figure 5 Wind velocity at 20cm in banding collocate

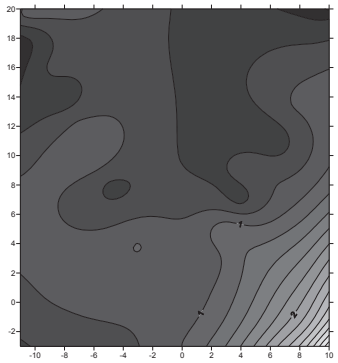


Figure 6 Wind velocity at 50cm in banding collocate

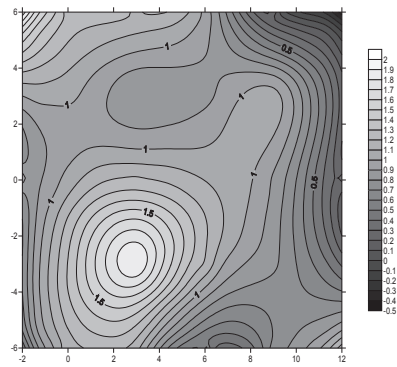


Figure 7 Wind velocity at 20cm in stochastic model

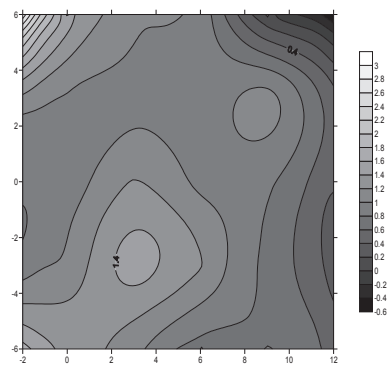


Figure 8 Wind velocity at 50cm in stochastic model